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Technology &
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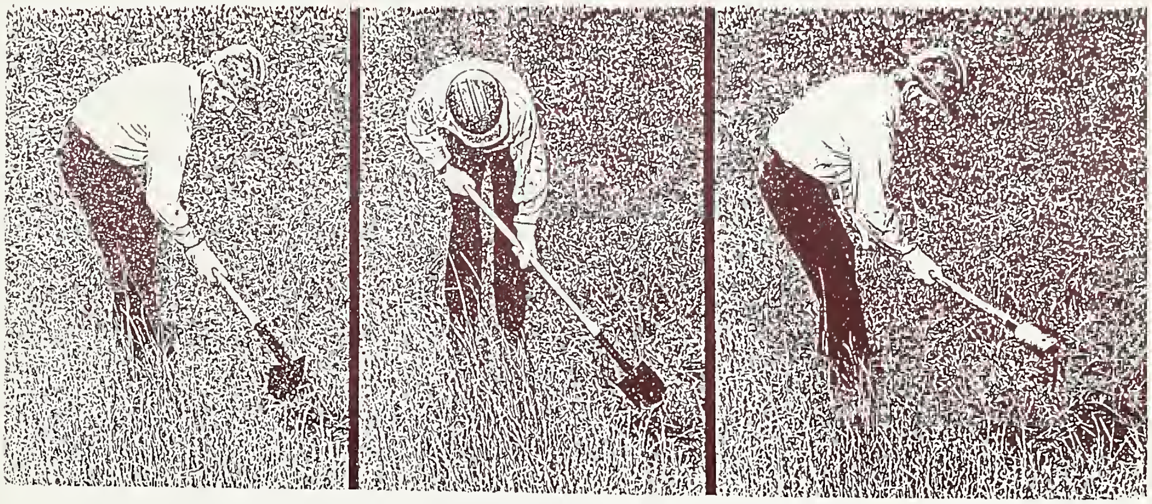
Program

Missoula, MT

An Improved Wild Land Firefighting Handtool



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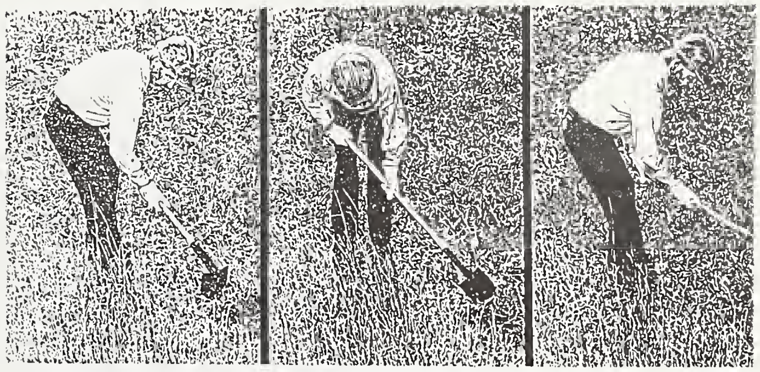

Arthur H. Jukkala, Forester

Brian J. Sharkey, Ph.D., Exercise Physiologist,

1E12P33 Fire Handtool Improvement
Fire Management

Project Report

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USDA Forest Service
Technology and
Development Center
Building 1, Fort Missoula
Missoula, MT 59801

Contents

Summary

Our objective was to identify or develop a fireline digging tool that required less physical effort to produce an equal or greater amount of fireline than tools now used. The efficiency of three common tools (Pulaski, adze hoe, and McLeod) and three lesser known tools (super Pulaski, Reinhart, and Fyr-Tamer) was compared in controlled tests. Efficiency was defined as the amount of fireline produced versus the amount of energy expended to produce the line. Energy expenditure was measured in liters of oxygen consumed to accomplish the work. Controlled tests consisted of a series of 3-minute-long trials with different tools. The initial tests were followed by a field evaluation. All tools tested had some deficiencies, so an effort was launched to develop a better fireline handtool. The result was the combination tool or "Combi" tool, which is basically a modified 1950's vintage military intrenching tool that can be used as a hoe, pick, hoe-pick combination, or shovel.

The combination tool proved to be about 20 percent more efficient than the Pulaski and slightly more efficient than other fireline digging tools studied. Although the tests were short, the findings suggest that as workers tire during several hours of digging fireline, the combi tool's greater efficiency becomes even more pronounced. Results showed that five combination tools in a 20-person crew using Pulaskis increased production equal to adding one person to the crew.

The combination tool proved to be a better fireline-digging tool than the Pulaski in difficult digging conditions like bear grass and rock. It can chop roots, small trees, and brush up to 1½ inches in diameter. It can limb trees and is a good hotspotting and mopup tool. Because of its versatility, the combination tool can lower packout weight of smokejumper gear by reducing the number of tools that a pair of jumpers carry. This concept might also reduce weight and bulk in smoke chaser and helitack fire packs.

The combi tool does not have chopping capabilites. It is not intended as a replacement for the Pulaski but complements it to accomplish more efficient and safer firefighting.

Acknowledgments

The authors wish to acknowledge Gordon Reinhart, Fire Management Officer on the Umatilla National Forest, Pacific Northwest Region, and Ben Lowman, Missoula Equipment Development Center mechanical engineer, for their contributions in developing a new firefighting handtool. We also thank the staff of the Missoula Ranger District, Lolo National Forest, for providing subjects and test sites for our tool evaluations, and the Forest Service Southwest Region for financing a significant share of the 1985 purchase of combination tools for field evaluation.

Introduction

Wild land firefighting is arduous. It requires a high level of aerobic and muscular fitness, as well as muscular strength. Unlike many jobs that allow employees to pace themselves, it is the fire that paces the worker. And unlike many industrial jobs, the firefighter's work environment can't be altered to ease the job. The Forest Service has specific hiring standards to ensure that only fit, skilled employees work on the fireline. The physical demands and danger inherent in the job serve as employment restrictions and many people find the job too physically demanding. Understandably, opportunities for making the job easier are major Forest Service goals.

Despite significant advances in wildfire suppression technology in the past three decades, fireline constructions and mopup are still accomplished largely by workers wielding handtools. Yet, except for the firefighters' shovel, the primary firefighting handtools—Pulaski, brush hook, McLeod, council tool, and adze hoe— have undergone no major design changes that make them more productive or easier to use.

The Missoula Equipment Development Center (MEDC) was asked to find or develop a lighter, more efficient handtool that would make the firefighting job easier and safer. Our objectives were: (1) Identify significant productivity and energy cost differences among fireline tools; (2) Identify tool design characteristics that increase production and reduce energy costs; and (3) Locate tools or design a tool that helps make fireline digging easier and more efficient.

Commonly used handtools were tested under controlled field tests. Initial findings indicated that a better handtool could be designed. A series of tool design and test sequences led to the combination or "Combi" tool, which we believe meets wildfire agency needs for productivity and efficiency. This report describes the development program that resulted in this new and versatile handtool.

Initial Controlled Tests

The Tools

We selected six tools for digging simulated fireline. One, the Pulaski, is the single most common wild land firefighting tool next to the shovel. Shovels were not tested because they are commonly used for cleaning out fireline after the Pulaski and other tools have dug the initial line. Two other tools, the adze hoe and McLeod, are used for specific ground cover conditions in certain parts of the western United States. Three less well-known tools, the super Pulaski, Reinhart, and Fyr-Tamer were also tested.

Pulaski—The all purpose wild land firefighting tool in the West. The matlock end is used for digging fireline and mopup tasks. The ax blade gives the tool its multipurpose capability (Fig. 1).

Figure 1.—Pulaski.

McLeod—A combination hoe and rake for fighting fires where pine needles and other litter are the primary ground cover. Commonly used in Arizona, New Mexico, and California (Fig. 2).

Adze Hoe—This tool's primary job is scalping spots for tree planting. It is also used for digging fireline in deep duff, primarily in Washington and Oregon (Fig. 3).

Figure 2.—McLeod.

Figure 3.—Adze hoe.

Super Pulaski—A modified Pulaski with a wider hoe blade. A Forest Service hotshot crew in California came up with this idea to improve the Pulaski's line-digging capabilities. Most hotshot crews in California have several of these tools (Fig. 4).

Figure 4.—Super pulaski.

Reinhart—Designed primarily to construct control lines for prescribed burns. It has been used in Washington and Oregon for wildfire control and site preparation. As originally designed by Forest Service employee, Gordon Reinhart, the tool had an 8-pound maul handle. A shovel handle was retained in the tools tested for this study (Fig. 5). For simplicity in this report the modified tool is referred to as the Reinhart.

Figure 5.—Reinhardt (modified).

Fyr-Tamer—A commercial version of the Reinhart tool, with some significant differences. An adze handle replaces the maul handle. The blade is different in weight, size, and shape (Fig. 6).

Figure 6.—Fyr-Tamer.

Test Methods

To determine the energy cost, production rate, and efficiency of these six handtools, we developed a lightweight, portable expired-air collection system for data gathering in the field. It consisted of a breathing valve, hose, and meteorological balloon inserted into a nylon bag attached to a webbing shoulder harness (Fig. 7). The air samples gathered from test subjects as they dug line with the different tools were analyzed with an oxygen consumption computer to determine the energy cost of tool use.

Work production was measured in feet of fireline dug. Fireline was constructed to a standard width of 18 inches. Energy cost for the task was measured and recorded in liters of oxygen per minute. We then determined tool efficiency by calculating the feet of line constructed per liter of oxygen used. Finally, to compare individual workers, we divided the oxygen cost per unit of work by body weight to get the oxygen cost of production per unit of body weight.

A series of trials was conducted to determine the validity of our test equipment and test protocol. These trials revealed that our data gathering equipment had the accuracy to reveal differences in the energy cost per unit of production of 3 percent or more.

We divided our line digging tests into two phases. The first phase consisted of one subject using the six tools in a series of repeat trials. The second phase consisted of six people from a ranger district fire crew digging line with the tools.

Figure 7.—Expired-air collection system.

Single-Subject Tests

An experienced firefighter served as the subject. The purpose of this phase of testing was to make final changes in the test protocol and to determine possible sources of error in the procedures.

The subject used all the tools under what we defined as medium and easy digging conditions. Conditions were rated according to the vegetative cover, soil, rock, and other factors involved in line production. We attempted to provide similar digging conditions for each tool, but normal variation made that impossible.

The subject worked for 3 minutes with a randomly selected tool, rested, worked with another tool, then rested. This routine was repeated for each tool. The subject dug fireline to mineral soil at a pace that could be sustained for a normal shift. After 2 minutes of steady work, the subject opened the air collection valve and continued working for the final minute as expired air was collected. At the end of the minute, the subject turned off the collection valve, indicating an end to the trial.

An observer timed each trial, ensured fireline quality (width and depth), measured feet of line dug, and recorded the time of data collection and air sampling. Air samples were immediately evacuated into the oxygen consumption computer. The subject worked with each tool several times over a 4-day test period. The observer recorded the subject's subjective evaluation of each tool.

As in the pilot tests, this phase of our testing indicated that our data gathering was accurate and measurement errors of less than 3 percent could be expected.

Under conditions of medium digging difficulty, the Fyr-Tamer and super Pulaski, (4.2 feet per minute) outperformed the least productive tool, the Pulaski (2.7 feet per minute) by 56 percent (Table 1). The Fyr-Tamer proved the most efficient tool at 3.1 feet dug per liter of oxygen consumed. The Pulaski was least efficient. The cost per unit differences among the tools ranged from 4.4 mililiters of oxygen per kilogram of body weight per foot of line dug per minute for the Fyr-Tamer to 6.9 for the Pulaski, a 30 percent difference. The differences in efficiency and energy costs among tools were far less dramatic when digging conditions were easier (Table 1).

Table 1—Single-subject comparison of handtools[1]

Tool	Feet of line (ft/min)	Oxygen cost (liter/min)	Efficiency (ft/liter)	Cost/Unit (ml/kg/ft/min)
		Medium Digging Conditions		
Fyr-Tamer	4.2	1.42	3.1	4.4
McLeod	3.6	1.36	2.6	4.7
Adze hoe	3.4	1.52	2.3	5.6
Super Pulaski	4.2	1.49	2.8	4.5
Pulaski	2.7	1.47	1.9	6.9
Reinhart (modified)	3.4	1.49	2.3	5.4
		Easy Digging Conditions		
Fyr-Tamer	5.6	1.72	3.3	4.0
McLeod	4.8	1.65	2.9	4.3
Adze hoe	5.3	1.66	3.2	4.0
Super Pulaski	5.6	1.73	3.2	3.9
Pulaski	5.2	1.64	3.2	4.0
Reinhart (modified)	5.8	1.50	3.7	3.2

[1] Mean of three trials with each handtool.

Fire Crew Tests

For this phase of the tool study, six members of the Lolo National Forest Missoula Ranger District fire crew acted as subjects (Table 2). Their firefighting experience varied from one to several seasons. Due to reassignment, one crew person had to be replaced midway through the data collection.

Table 2—Profile of fire crew subjects

	Men	Women
Number	4	2
Average		
Age	23.4	26
Height	5 ft 11 in	5 ft 7 in
Weight	170 lb	148 lb
% body fat	8	24.8

These tests followed the procedure established in the single-subject test. In addition, a randomized latin square was used to arrive at the order in which the six tools were tested. It also allowed us to identify differences in tool performance due to a subject's skill, strength, and fatigue, so that such individual characteristics would not bias tool performance.

Tools were tested at two different sites under what we rated as medium and difficult digging conditions. Subjects used each tool in each condition. Both sites had vegetative covers of beargrass, pine grass, huckleberry, and nine bark. The site rated as difficult had a heavier beargrass cover and the soil contained more rock. At the end of testing, production and energy cost data showed that the difficulty in digging at the two sites proved to be similar.

In the site conditions classed as medium, the most productive tool, the super Pulaski (3.9 feet of line per minute) outperformed the least productive, the Pulaski (3.1) by 26 percent (Table 3). The most efficient tools—McLeod, super Pulaski, and Reinhart (2.4 feet of line per liter of oxygen consumed) proved 26 percent more efficient than the Pulaski. And the cost per unit of production for the tools (6.0 for the McLeod and Reinhart versus 7.8 for the Pulaski) differed by 30 percent. Differences in the conditions classed as difficult showed less variability in productivity and efficiency among the tools (Table 3). However, the difference between the low cost per unit McLeod (5.5) and the high cost Pulaski (7.6) was 38 percent in the difficult conditions (Table 3).

Table 3—Fire crew comparison of handtools[1]

Tool	Feet of line (ft/min)	Oxygen cost (liter/min)	Efficiency (ft/liter)	Cost/Unit (ml/kg/ft/min)
		Medium Digging Conditions		
Fyr-Tamer	3.7	1.51	2.2	6.6
McLeod	3.7	1.58	2.4	6.0
Adze hoe	3.8	1.63	2.3	6.1
Super Pulaski	3.9	1.64	2.4	6.1
Pulaski	3.1	1.68	1.9	7.8
Reinhart (modified)	3.8	1.61	2.4	6.0
		Difficult Digging Conditions		
Fyr-Tamer	3.5	1.48	2.3	6.2
McLeod	3.7	1.57	2.2	5.5
Adze hoe	3.7	1.50	2.5	5.9
Super Pulaski	3.5	1.61	2.2	6.7
Pulaski	3.3	1.58	2.1	7.6
Reinhart (modified)	3.6	1.44	2.6	5.8

[1] Mean of two trials with each tool.

Individual Subjects and Tool Performance

The latin square design allowed an objective assessment of tool productivity. It also allowed us to analyze individual differences and possible interactions between subjects and tools. Table 4 compares individual production and efficiency data for six crew members and the more experienced individual firefighter.

Table 4—Individual differences in production and efficiency[1]

Single-subject	Crew Members	Feet of line (ft/min)	Efficiency (ft/liter O^2)	Cost/Unit[2] (ml/kg/ft/min)
Art		3.6	2.5	5.2
	Myron	4.2	2.5	6.4
	Al	4.4	2.5	6.0
	Wes	3.4	1.9	5.8
	Jim	3.7	2.3	7.1
	Mary	3.0	1.9	7.8
	Nan	3.3	2.4	6.3

[1] Average of six tools in medium digging conditions.
[2] A measure of worker efficiency; high cost per unit of production is inefficient.

It is clear that individual differences in performance and efficiency were present. Some subjects were clearly more skilled with tools than others. The most experienced firefighter was 33 percent more efficient than the least efficient (5.2 vs. 7.8 ml/kg/ft/min). Strength could also account for some of the differences.

We conducted a statistical analysis of sources of variability. The analysis showed that individual differences accounted for 45.1 percent of the variability in performance; the tools themselves accounted for 26.3 percent, variable digging conditions accounted for 26 percent. Measurement error, including timing and measuring of production, accounted for 2.6 percent.

Clearly individual differences overshadow tools or digging conditions in terms of their effect on performance. The data suggest that the most obvious way to increase performance is to hire skilled, fit workers. However, it also shows that proper tool selection can enhance performance significantly. The ideal tool for a given condition is one that is both high in production and low in cost to the user.

We also ranked the tools by productivity in the hands of the different subjects (Table 5). Variations in digging conditions probably explain some of the differences in performance with a given tool. Fatigue, strength, endurance, stature, or physique could account for differences, as well.

Workers generally preferred longer handles that allowed them to work in a more upright position. Shorter subjects might be more comfortable with shorter handles. What does emerge from this analysis is that most of the tools performed similarly except for one, the Pulaski, which was consistently less productive.

Table 5—Productivity (ft/min) ranking of tools[1]

Tool	Wes	Jim	Myron	Al	Mary	Nan	Art	Sum of Ranks	Mean Rank
Fyr-Tamer	2	4	4	2	6	3	1	22	3.14
McLeod	3	2	5	3	2	6	3	24	3.43
Adze hoe	4	5	6	1	1	2	5	24	3.43
Super Pulaski	5	3	1	4	5	1	2	21	3.00
Pulaski	6	6	2	6	4	5	6	35	5.00
Reinhart	1	1	3	5	3	4	4	21	3.00

[1] = best performance.

Medium digging conditions.

Characteristics of Tools

We compiled some tool characteristics that could help explain the differences in production found in the test results (Table 6). The tools actually differed more in design than in performance. The least productive tool, the Pulaski, had the smallest cutting blade. This may be one reason it performed so poorly in the moderate and difficult digging conditions. The blade seemed to penetrate deeply into the soil and often required considerable effort to remove it. The other tools penetrated far enough to cut roots and remove beargrass without hanging up. Another factor in tool design was handle length and shape. The subjects felt that the tools with longer handles minimized low back fatigue.

A more subtle aspect of tool design is the angle of blade to handle and the manner in which the blade is sharpened. For scraping purposes, the ideal angle would seem to be one that guides the tool over soil rather than into it. The Pulaski is sharpened for digging rather than scraping (Fig. 8) and that may be one reason why it tends to be difficult to retrieve. We believed these and other aspects of tool design deserved more study.

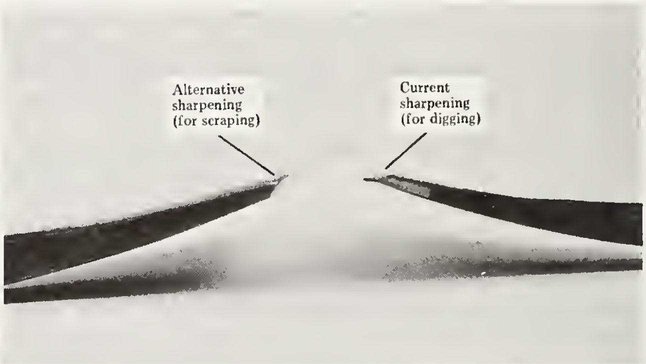

Figure 8.—Pulaski hoe sharpening.

Table 6—Characteristics of fireline construction tools

Tool	Blade width (in)	Tool weight (lb)	Weight/width (lb/in)	Overall tool length (in)
Fyr-Tamer	7.75	4.61	0.59	35½
McLeod	9.75	4.94	0.46	50
Adze hoe	6.12	5.40	0.88	35
Super Pulaski	6.00	6.16	1.03	34½
Pulaski	3.31	5.23	1.58	34½
Reinhart	7.25	3.69	0.51	41

Tool Comparison Test

We conducted another controlled test to find out what effect handle length had on productivity and efficiency. Two subjects did three trials with two different modified Reinhart tools. The two tools differed in handle length, weight, and blade width (Table 7a):

Table 7a—Productivity and efficiency based on handle length

	Handle length (in)	Weight (lb)	Blade width (in)	Weight/width (lb/in)
Reinhart 1	41	3.69	8.0	0.46
Reinhart 2	48	3.85	9.5	0.41

The subjects alternated use of the tools while digging line in a field of bunchgrass. Production and energy cost data were collected as before.

For one subject—the experience firefighter who was the single-subject in the first phase of our controlled tests—production between the tools differed little (Table 7b). However, the long handle was 8 percent more efficient; that is, it cost that much less energy to dig a given amount of line. The second subject, a smokejumper, produced 10 percent more with the long-handle tool. The cost per foot of line was 12 percent less with the long handle. Both subjects said the long handle would cause less low back fatigue during a long work shift.

Table 7b—Effect of handle length on production and efficiency

	Subject 1	(77 kg body wt)		Subject 2	(74.7 kg body wt)	
	ft/min	ft/liter	ml/kg/ft	ft/min	ft/liter	ml/kg/ft
Reinhart 1 (short)	3.8	2.4	5.4	4.7	2.4	5.6
Reinhart 2 (long)	3.85	2.6	5.0	5.2	2.7	5.0

Summarizing Controlled Test Findings

Our controlled tests of six tools used in fireline digging revealed some significant differences in production and efficiency among them. Surprisingly, the Pulaski, the tool most often used in fire suppression, was the least efficient for digging fireline. Although the 3-minute trials could not reflect production for an entire shift, the Pulaski's short handle and small blade could prove an even bigger burden as the work period is extended.

The Pulaski can do two jobs. It can chop as well as scrape, so some compromise is acceptable. However, the chopping side of the Pulaski is a compromise as well, and in some cases, the chopping might be accomplished more efficiently with an ax. Study of tool use by crew supervisors should help determine the need for the dual purpose tool. Where feasible, it will be more productive to equip workers with a mix of tools that are well suited to the task and conditions—the right tool for the right job.

These data were based on a small sample and limited trials. To be able to reach meaningful conclusions about tool efficiency and productivity, we needed more data from workers under actual field conditions.

1982 Field Evaluation

Based on the results of our controlled tests, we decided to conduct a field evaluation of the Reinhart and Fyr-Tamer. At the outset, it was clear that both had deficiencies as an optimum fireline construction tool. Nevertheless, our controlled tests showed that tools of this general design offered potential for increased production at lower energy cost.

Our data also indicated that the super Pulaski was one of the more productive tools. But the data showed that the super Pulaski's energy cost was among the highest in difficult digging. We were also concerned about the tool's safety. Field reports during the past several years indicated that some people fit enough to pass the step test and qualify for firefighting work had insufficient grip and forearm strength to control and safely use the Pulaski. Watching subjects digging with the super Pulaski, which has a wider hoe blade, suggested that people with low grip and forearm strength would have even greater difficulty using this tool safely. Subjective unstructured chopping trials reinforced this concern. While the super Pulaski can be a good tool in the hands of a strong, fit person, it could be a liability and safety hazard to a large percentage of firefighters. For these reasons we chose not to evaluate the super Pulaski further.

Evaluation Method

One Fyr-Tamer and three Reinharts were sent to 11 hotshot crews in the Forest Service Northern, Pacific Southwest, and Pacific Northwest Regions and one ranger district brush crew in the Northern Region. Users were instructed to evaluate the tools for safety, performance in fireline construction and mopup, overall performance, maintenance, and specific design features. In addition, each tool user was given a questionnaire to complete; hotshot superintendents were given separate questionnaires to fill out (Appendix A).

Results

Seven crew superintendents completed and returned their questionnaires. All responded that these tools have a place in fire suppression work. There was also fair agreement on these points:

(1) The Reinhart is the better configuration of the two tools. The Reinhart's weight and longer handle are the major reasons for its superiority.

(2) Both tools work best in soft, loose soils. Both were hard to control in rocky soils.

(3) Both tools work well for cut trenching, scraping, or cleaning fireline.

The comments from 27 individual tool users generally paralleled those of the superintendents:

(1) The Reinhart was preferred over the Fyr-Tamer for both line construction and mopup. However, respondents rated the Pulaski, super Pulaski, and shovel better for these same jobs.

(2) The Reinhart was judged to be slightly less fatiguing than other fireline construction tools. Most respondents said it produced less hand, arm, and lower back fatigue than other fireline tools.

(3) Most felt the Reinhart's handle length was satisfactory but that the Fyr-Tamer handle was too short.

(4) Respondents reported problems with soft steel in the blades of both tools and the need to sharpen them often.

These subjective responses conflict with the objective data on production and efficiency. This could be due, in part, to a preference for the traditional tools and a resistance to change.

No major safety concerns emerged. Some comments were made about both tools bouncing and glancing. Overall, respondents suggested both tools were easier and safer to use than many fireline digging tools.

A summary of the individual evaluator responses to the questionnaire is included in Appendix A.

Developing A Better Handtool

Concurrently with the 1982 field evaluation, MEDC began working to develop a more effective tool. Ben Lowman, an MEDC mechanical engineer, had been working with handtools for scalping tree planting spots. He urged us to modify a military intrenching tool. With the intrenching tool as the basis, we made several prototypes with different size blades. We also made the prototypes so the hand-to-blade angle could be varied and handles of different lengths and shapes could be fitted to the blades.

Preliminary Trials

A group of MEDC employees dug fireline with each prototype. We reached quick agreement about the blade. Our unanimous choice was the military intrenching shovel. It was more optimum than the size 0 or 1 shovel blades evaluated. We were less certain about the best handle-to-blade angle or handle. An angle of about 80 degrees appeared to be best.

Several prototypes were fabricated. A few had size 0 shovel blades and others the military intrenching shovel blade. All had a feature for adjusting the handle-to-blade angle. Each was fitted with a ferule that would accept different handles. Pulaski handles of wood and fiberglass, adze, shovel, McLeod, and an 8-pound maul handle were all fitted to the ferule.

These prototypes were provided to a brush crew from the Powell Ranger District, Clearwater National Forest, and a Bitterroot National Forest hotshot crew. These crews were digging control lines for a prescribed burn. Both crews also had the Reinhart and Fyr-Tamer.

Below are excerpts from crew reports. Their complete reports are included as Appendix B:

> *Powell Ranger District Crew—"People generally liked this tool [intrenching tool concept]. Taller people liked the longer handle and the adjustable feature. They preferred wood over fiberglass because of less shock and more durability. People experimented with different blade angles, but everyone seemed to prefer the 90-degree angle that we always use. However, if this feature is kept, the head clamp must be improved as it kept*

coming loose while digging. For myself, the ability to change from a scraping tool to a shovel is a nice feature. Overall, the tool was well liked, it is compact, light, and easy to use, and it is good for scraping or rescraping mineral soil. It is not much use for chopping."

Bitterroot Hotshot Crew— ". . . The consensus of opinion regarding the effectiveness of these tools is positive. Most people that tried them felt that there was a definite place for them in the tool lineup . . . They seem to ease the back strain and made building line downhill easier . . ."

"The blade configuration that was preferred was that of the Army intrenching tool. That was unamious among the people who used the tools . . ."

The field evaluation confirmed that the Reinhart and Fyr-Tamer tools had design deficiencies. This fact, plus the limited but promising field performance of the modified intrenching tool, persuaded us to refine and evaluate this tool concept further.

1983 Field Evaluation

Evaluation Method: For the 1983 field season, some 50 intrenching tools were manufactured in the MEDC shops. The tools were made by fitting the military folding lightweight intrenching tool (FLIT) (Figs. 9, 10) to a specially milled 40-inch-long maul handle, giving the tool an overall length of 46 inches. After the limited experience in 1982, we felt this overall length and handle shape would allow good tool control while minimizing fatigue to forearms and lower back.

We wanted to produce the tool with a pick and obtained a large quantity of 1950 vintage military intrenching tools that had picks. (The new FLIT does not.) Unfortunately, we encountered problems adapting these tools to a long handle, so abandoned the idea and used the FLIT instead. However, a few tools were made with a pick for testing at MEDC.

Of the 50 modified intrenching tools manufactured for field evaluation, four tools plus evaluation questionnaires went to 11 hotshot crews in the Northern, Southwest and Northwest Regions. Four more were provided to the smokejumper project in Missoula. The questionnaire and a partial summary of responses are included in Appendix C.

The tool was referred to as the modified Reinhart for the 1983 field evaluation. However, later, as a pick was added and the tool obviously became a modified intrenching tool, we changed the name to the combination tool, or "combi" tool.

Results: Here is a brief summary of what evaluators told us:

(1) The tool has a major place in wild land suppression work.

(2) Being able to convert the tool from a shovel to a hoe was valuable.

(3) The tool was used primarily in a hoe configuration.

(4) Out of seven tools, evaluators ranked the tool third behind the shovel and Pulaski as being the preferred choice on small fires and mopup.

(5) Most evaluators felt the handle was satisfactory, but many reported that the locking nut often needed tightening.

(6) A number thought the blade should be more durable and the cutting edge harder.

Figure 9.—Tool in hoe configuration.

Figure 10.—Tool in shovel configuration.

Additional Controlled Tests

At the same time the field evaluation was underway, we began more controlled tests. Our objective was to help answer questions about the best design for a fire handtool. Our major questions were:

(1) How does the modified intrenching tool compare with other fire handtools in production and efficiency?

(2) How does the Pulaski perform when it is sharpened on the reverse side (a question raised by the first controlled tests)?

The firefighter who was our single-subject during our first controlled tests again served as a subject to compare four tools: Pulaski, Reinhart, modified Pulaski, and the combi tool.

The controlled fireline production protocol used in earlier studies was followed. The subject worked with the four tools in a random order in moderately difficult digging conditions. Our data gathering yielded measures of production in feet per minute, oxygen intake, and production per unit of oxygen consumed (feet of line per liter of oxygen).

The combi tool outproduced the Pulaski by almost 18 percent (Table 8). When tool efficiency was considered, the combi produced more line per unit of energy expenditure. The combi was 20 percent more efficient than the Pulaski. The modified Pulaski, sharpened to enhance scraping, proved less productive and less efficient than the Pulaski. Depite the fact that the standard Pulaski sometimes hangs up and takes extra energy to free, the modified sharpening technique did not improve the tool's performance. In fact, as noted in field evaluations, it makes the tool more likely to bounce or skip and creates a safety hazard.

The Reinhart was slightly more productive (less than 3 percent) and efficient (6 percent) than the Pulaski. It was less productive (14.7) and efficient (13.3 percent) when compared with the newly designed combi tool.

During these trials, the combi tool seemed to cut and clear line at the same time, while the Pulaski required separate strokes to cut and then clear. Also, the combi seemed to clear a wider line with less effort. Several trials were conducted to compare strokes-per-minute and production-per-stroke between the tools. Our single-subject from the controlled tests used each tool in random order. Number of strokes were recorded along with line length and width (converted to areas of line produced).

Table 8—Tool comparison[1]

	Pulaski	Combi	Reinhart	Modified Pulaski
Production (ft/min)	4.42	5.21	4.54	3.85
Efficiency (ft/liter 0^2)	3.4	4.09	3.61	3.26

[1] Mean of two trials with each tool.

Again, the combi produced more feet of line (Table 9). And when width and length were considered the combi produced 15.7 percent more area of line without extra effort. The combi required fewer strokes, probably due to its wider blade and because it cut and cleared at the same time. Finally, the combi took 8.2 strokes per square foot of line versus 10.1 for the Pulaski; a difference of 23.7 percent. This difference was similar to the energy cost difference noted in current and previous oxygen intake trials. In other words, extra strokes take extra energy and could lead to premature fatigue.

Table 9—Strokes and square feet of production[1]

	Pulaski	Combi	Percent difference
Ft/min	3.88	4.25	9.5
Sq ft/min	6.10	7.06	15.7
Strokes/min	61.50	57.50	6.9
Strokes/ft^2	10.14	8.20	23.7

[1] Mean of two trials for each tool.

Again, these tests were short compared to long firefighting work shifts. However, work fatigue research suggests that productivity differences will become even greater during a workshift on the fireline.

Work Task Experiments

Besides line digging, we tested the combi in a variety of situations to assess its versatility and effectiveness as a firefighting tool (Fig. 11). These subjective trials showed that the combi tool can limb trees to remove "ladder" fuels next to the fireline. It can chop roots, small trees, and brush stems up to 1½-inches in diameter. For hotspotting, soil can be loosened and accumulated using the tool as a hoe. Then the soil can be thrown, using the tool as a shovel. It is an excellent mopup tool. With the shovel blade and pick perpendicular to the handle, it is excellent for scraping char and embers from burning logs. In this same configuration it can be used to "garden" hot spots and dig around stumps and roots.

The combi tool was also used in a wider variety of cover type and digging conditions than the more consistent ones selected for the controlled tests. These trials revealed that in loose litter such as a pine needle carpet, the tool can be turned on its side to put more blade on the ground for scraping and cleaning. This technique also works well in cleaning constructed fireline. The tool with pick extended works very well in constructing line in rocky soils. The pick can be used to remove loose rocks and clean out between larger rocks without the trauma associated with the tool head bouncing off rocks like the Pulaski does.

Figure 11.—From left to right, hoe, shovel, and pick configurations.

Refining Combi Tool Design

As mentioned before, we added picks to a few combi tools to increase versatility and effectiveness and add head weight for better tool balance. The increased weight reduced tool head bounce.

Reports from field users and our own observations during controlled tests indicated that adding a pick would be beneficial. Combi drawings with pick were prepared and sent to several fire handtool manufacturers for review and comment. We were looking for a firm willing to make a pilot lot of tools to resolve any production problems and to provide a small supply of tools for final field evaluation. A number of companies expressed an interest.

Our visit to the Ames Co. plant in Parkersburg, WV, proved most productive. Ames informed us that they had been the contractor for the Army's FLIT, and would have no trouble producing the combination tool. None of the other manufacturers contacted or visited was interested in producing the tool in small lot quantities, but they expressed an interest in bidding on larger General Services Administration contracts later.

Ames first manufactured a few tools for MEDC examination. Next a contract for a pilot lot of 300 tools was negotiated. These tools were scheduled for evaluation during the 1985 field season. (Thirty of the 300 were used in a study of site preparation tools MEDC was conducting.)

Smokejumper Version

Once the combi's final design was resolved, we developed a takedown version for smokejumper fire packs. Because of the combi's versatility and production potential, we felt this tool could help reduce packout weight.

Currently, smokejumper fire packs contain two Pulaskis and one shovel. These three tools weigh about 15 pounds. MEDC proposed replacing these three tools with one combi tool and one Pulaski. This would provide one less chopping tool, but add a more effective line digging and mopup tool, and would save about 5 pounds.

Smokejumper base managers agreed to field evaluate the proposed system and 50 tools were modified for this purpose. The modifications were simple. A rivet pinning the handle in the tool head was removed and replaced with a thumb screw and wing nut. Though not an elegant solution, this modification allows the tool to be taken apart so it can fit into the smokejumper pack. In addition, the handle was shortened by cutting 3 inches off of the end (Fig. 12).

Figure 12.—Smokejumper version of combi tool.

1985 Field Evaluation

The purpose of this field evaluation was threefold: (1) Obtain broader input on the combi tool's usefulness or place in wild land firefighting work so a determination can be made regarding the desirability of operational implementation. (2) Identify any design deficiencies that need correction before large scale procurement. (3) Determine if this tool will allow a reduction in the number of tools smokejumpers carry to reduce packout weight.

Evaluation Method: Approximately 110 tools were distributed to hotshot crews in Regions 1, 4, 5, and 6, plus the Bureau of Land Management and National Park Service. Another 64 tools went to smokejumper units in the same Forest Service regions. Additionally, the Southwestern Region provided funds for 80 tools, which were sent to hotshot crews in Arizona and New Mexico.

Evaluation objectives were explained to the participating proups and a supply of questionnaires accompanied the tools (Appendix D). A video tape was made describing the tool's key features. Copies were sent to Forest Service regions for circulation to participating hotshot crews. Also, copies were made for each smokejumper unit.

Results: Results were obtained in two ways: (1) personal interviews on fires with crews evaluating the tools and (2) a summary of questionnaire responses.

Personal interview data were obtained several months before written responses to questionnaires were received. These interviews confirmed our belief that the tool has a definite place in the arsenal of firefighting handtools. They also confirmed another feeling that we had: one must use and give the tool a fair evaluation to become convinced of its capabilities. Several firefighters admitted that initially they didn't think much of the tool by looking at it. However, once they used it, they were impressed with the tool's capabilities and performance.

These interviews revealed the following design deficiencies:

1. A problem with handle breakage where the handle fits into the steel socket.

2. Locking nut freezing. This resulted in many people leaving the tool in the hoe/pick configuration and losing the versatility of converting the tool to a shovel.

3. Blade steel too soft, requiring frequent sharpening.

Immediately after learning of these problems, we began to work with the Ames Co. to correct them. Solutions were found to all of these deficiencies.

A summary of questionnaires from 56 respondents showed the tools were used approximately 3,000 hours for constructing fireline and 2,400 hours for hotspotting and mopup (Appendix D). Sixty-six percent of respondents felt the tool has a major place in wild land fire suppression work. Only 5 percent felt the tool had no place in this work.

For line construction on both large and small fires, firefighters were asked to give their preferred choice of tools for fireline construction and mopup among the combi, Pulaski, McLeod, adze hoe, and super Pulaski. Reports show the Pulaski to be clearly the preferred tool by 2 to 1 over the combi, with a write-in vote for the shovel as a distant third choice. For mopup, the combi was the first choice of respondents, with the shovel and Pulaski being second and third, respectively.

Regarding design features, 66 percent of the responses indicated the handle needs no improvement. Fifty percent indicated the knuckle joint and locking nut are unsatisfactory. The majority of responses indicated the blade and pick need no improvement. However, 8 respondents requested that the serration now on only one side of the blade be incorporated into the other side. This action was already taken based on a few comments obtained in the personal interviews.

Responses to a performance comparison matrix (Appendix D) indicated that compared to the Pulaski, the combi tool:

1. Is about equal in fireline production and mopup capabilities.

2. Results in slightly less hand and arm fatigue but significantly less lower back fatigue.

3. Is somewaht easier to control and safer to use.

4. Requires less sharpening but more maintenance. (Maintenance involves tightening the head pivot bolt and cleaning, and keeping the locking nut operating freely. These tasks can usually be done in camp or between fires.)

To summarize, verbal and written reports answered objectives 1 and 2 of the field evaluation. The responses reinforced previous reports that the combi tool has a significant place in the firefighting tool arsenal (objective 1). The evaluation also identified minor design deficiencies (objective 2).

Due to a very active fire season and late delivery of modified combi tools to smokejumper units, they did not fully evaluate the tool. Their evaluation reports were few and objective 3 was not entirely met. Use of the combi tool was discussed at the 1985 smokejumper unit managers meeting. The smokejumper units plan to extend their evaluation of this tool into 1986.

Discussion

This project was funded to find or develop a lighter, more efficient handtool that would help make the firefighting job easier, particularly for people with less upper body strength. Our objectives were basically threefold: (1) Look for significant productivity and energy cost differences among existing firefighting handtools. (2) Identify tool design characteristics that increase production and reduce energy costs. (3) Identify tools or design a tool that helps make fireline digging easier and more efficient.

Using a combination of controlled tests and field tests, we feel these objectives have been met. Both controlled and field tests indicate that the combi tool is capable of producing equal or more fireline with less overall user fatigue than the current most popular and widely used firefighting tool, the Pulaski. As measured in controlled tests, reduced worker fatigue can be expected due to lower energy cost in mililiters of oxygen per kilogram of body weight per unit or area of fireline constructed. Field reports indicate that hand, lower arm, and lower back fatigue will also be less.

Several design deficiencies were identified in the 1985 field evaluation. By working with the manufacturer of the prototype tools, we have corrected these deficiencies and incorporated the changes in the procurement specifications. Operational use of the tool will no doubt reveal other deficiencies. However, we feel the design is fairly well refined and that the revised specifications will provide a good tool.

Some questions remain regarding the size of the blade and shape of the handle. A few people feel the blade should be larger, about the size of a number 0 shovel, a few feel the handle should be round. Some suggest using the McLeod tool handle. The future may show that these design changes should be made. However, the bulk of the data favors proceeding with the existing design. As deficiencies are found or as opportunities for improvements are identified, they should be made.

Many experienced firefighters expressed a concern that the Pulaski will be replaced with the combi tool. This is definitely not the case. Because of its dual function as a chopping and digging tool, it would be virtually impossible to replace the Pulaski. The combi and Pulaski will complement each other. In a 20-person crew, we suggest replacing four to five Pulaskies with combi tools to give the added line digging capability equivalent to adding another person to the crew. The added efficiency to mopup operations may be even greater.

Conclusions

1. Our initial controlled tests and field evaluations indicated that a more efficient handtool could be developed for digging control lines on wild land fire.

2. These studies indicated that a wider blade hoe design, like the Reinhart tool, offered the most promise.

3. The combination or combi tool, produced more line per minute and required less oxygen per foot of line than other tools tested.

4. Controlled tests indicated that for digging fireline, the combi tool is approximately 20 percent more efficient than a Pulaski.

5. The combination tool lacks some of the multipurpose features of the Pulaski because it is not a chopping tool. However, MEDC experiments show that in addition to its superiority for digging fireline in a variety of conditions, including rock soils, it is a good limbing and hotspotting tool. More importantly, it is an excellent mopup tool. Training, exposure, and experience will be keys to acceptance of the combi tool. Widespread acceptance will take time.

6. Of all the tools tested, the Pulaski is the least efficient for digging fireline. However, due partly to its versatility and perhaps to tradition, it was often the preferred tool in field tests.

7. A question regarding proper sharpening of the Pulaski hoe was explored, and it was determined that the current sharpening method is correct.

8. The super Pulaski is a productive, efficient tool in the hands of a person with high forearm and grip strength. For others, it could be an unsafe tool, so production, manufacturing, and stocking do not appear prudent.

Recommendations

1. Correct design deficiencies reported in the 1985 field evaluation, then write a final specification.

2. We recognize that the combi tool design with 1985 deficiencies corrected might have some remaining deficiencies, but it appears to have enough merit to proceed with GSA stocking and field implementation. We recommend that 8,000 tools be purchased in the initial procurement. This quantity is small enough to minimize any risk related to poor or slow field acceptance. Yet, it is large enough to prorate tooling costs without creating a prohibitively expensive tool.

3. Film, reproduce, and distruibute an improved video tape on the combi tool to speed field acceptance.

Fire Handtool Field Evaluation

Background

The Missoula Equipment Development Center (MEDC) has been assigned a project to determine if any of the existing fire handtool designs are superior to the others for digging fireline. Superior is defined as a tool that produces more fireline for an equal amount of work effort or has comparable production capabilities for less work effort.

Instrumented field tests by MEDC last summer indicate that tools with wider scalping blades exhibit considerable promise for improved production and/or reduced work effort. Two tools that showed promise are the "Reinhartski," developed in 1972 by Forest Service employee Gordon Reinhart of Region 6, and the Fyr Tamer, which is a commercial version of the "Reinhartski."

One obvious shortcoming of these tools is that they do not have the dual chopping and digging versatility of the Pulaski. Discussions with many Interagency Hotshot Crew superintendents lead us to believe that most fireline clearing is being done with chain saws and that a chopping capability in all digging tools is not needed.

Tests at MEDC were for short periods and compared tools for digging only. The purpose of this field evaluation is to determine if experience in operational use confirms or repudiates data collected in MEDC controlled studies and to determine if the inability to chop with these tools poses any major problems. In view of the limitations of our study, we need your help to gather additional data under operational conditions to answer these questions.

We'd like to have your unit use one Fyr Tamer and three "Reinhartski" tools on fires this summer in lieu of some of your primary line digging tools and make subjective comparisons between the tools. In between fires, we'd like you to make more objective comparisons. This can be done by assigning a team of four people to dig X feet of line with Pulaski's and an equal number dig X feet with the three "Reinhartski's" and one Fyr Tamer. Use a stopwatch and measure and record the time it takes each team to dig X feet of line. Then have the teams switch tools and repeat the task. Switching tools eliminates differences in team performance and isolates differences in performance of the tools.

Please return completed questionnaires by November 1, 1982, to:

Art Jukkala
A&FM Staff Assistant
Missoula Equipment Development Center
Bldg. 1, Fort Missoula
Missoula, MT 59801
FTS 585-3164
Comm. (406) 329-3164

For controlled tests of this type you should consider the following:

1. Conduct the trials in several digging conditions, varying from easy to very difficult. Be certain you classify and record the difficulty of the digging conditions for the trials.
2. Make certain equal width line is produced by both teams. This is largely subjective but spot check measurements of width should be made to insure a minimum width of line. We suggest an 18-inch width as a minimum standard.
3. Do all major clearing that you would normally have a saw crew do before the digging trial begins.
4. Strive for uniform digging conditions for the teams. This can often best be done by staggering the starting times or allowing one team to fully complete its assignment, then digging the second line close to and paralleling the first line.

Field Evaluation Reporting

This field evaluation has two reporting forms, a **Crew Superintendent Reporting Form** and an **Individual Evaluator Questionnaire**. A brief explanation of each follows:

The purpose of the Crew Superintendent reporting form is two-fold: (1) As a supervisor, it provides a vehicle for you to summarize individual evaluator reports and comment on how you feel these tools might fit into fire management or other forestry field activities. (2) If you are able to conduct controlled tests, it provides a data recording form.

Please have tool users complete the Individual Evaluator Questionnaires. Crew superintendents should fill in the physical performance data on each tool user. This data will help us determine if there are any significant correlations between tool preferences and physical characteristics or capabilities of the user.

Some muscular fitness measurements of tool users are desired. These include the number of chinups, situps, and pushups each user can do. Procedures described in the enclosed MEDC publication *Fitness and Work Capacity Testing*, July 1977, should be followed with the following exceptions: Tool users should do as many chinups as each is capable of doing. They should then do as many situps as they can in 60 seconds followed by as many pushups as they can do in 60 seconds.

CREW SUPERINTENDENT REPORTING FORM

Fire Handtool Evaluation

Field Unit (Forest, District, etc.)	
Crew Name	
Superintendent	Date
Superintendent's Phone No. FTS	Commercial

Did you conduct controlled tests of the tools? ☐ Yes Complete Parts I & II
☐ No Complete Part I only

PART I – GENERAL EVALUATION

1. Do you feel the "Reinhartski"/Fyr Tamer type of tool has a place in fire suppression work? ☐ Yes ☐ No

2. Is one of these tools significantly better than the other? ☐ Yes ☐ No

   If yes, which one? Explain: ______________________

3. Describe the tasks, conditions, etc., under which this type of tool will yield the greatest benefits.

4. Describe any task, field condition, operator, organization, or other limitations of this type of tool.

5. Describe any changes that should improve the design of these tools.

   Reinhartski: ______________________

   Fyr Tamer: ______________________

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6. Any other comments: ____________________

PART II — TOOL COMPARISON TRIALS

TRIAL[1]	Total Digging Time Reinhartski + Fyr Tamer	Total Digging Time ______ Tool[2]	Difficulty of Digging[3]	Number of People Per Team	Feet of Line Dug
1A					
1B					
2A					
2B					
3A					
3B					
4A					
4B					

[1] In trial A, one team (preferably 4 per team) uses their usual line digging tool (specify which tool) and the other uses 3 Reinhartskis plus 1 Fyr Tamer; in trial B the teams switch.

[2] Record times for the digging tool used predominantly by your crew. On the blank, write name of tool.

[3] D — Difficult; M — Moderate; E — Easy

INDIVIDUAL EVALUATOR QUESTIONNAIRE

Fire Handtool Evaluation

Field Unit (Forest, District, etc.)	
Crew Name	
Your Name	Date

EVALUATOR INFORMATION

Weight ________ Height ________ Age _____ Male _____ Female _____ Aerobic Fitness Score(Step Test or 1½ mile run) __________

Muscular Fitness Data:

Chinups(no.) ________ Situps(no. in 60 sec.) ________ Pushups(no. in 60 sec.) __________

TYPE OF WORK PERFORMED

	Estimated Hours Used[1]	
	Reinhartski	Fyr Tamer
Line Construction—Wildfire		
Line Construction—Prescribed Fire Control Lines		
Line Construction—Fuelbreak or Other Presuppression		
Mopup		
Controlled Tests		
Other (explain)		

SAFETY

	For each tool describe nature of event as appropriate.	
	Reinhartski	Fyr Tamer
Accident	0	0
Serious Near Miss	1	2
Injury	0	0
Difficulty Controlling Tool	9	10
Other Safety Concern	5	4

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[1] Round off to nearest one-half hour.

PERFORMANCE COMPARISONS

For each category compare the Reinhartski to other tools you used.

FIRE CONSTRUCTION *For an equal period of use the Reinhartski produces:*	Pulaski	Fyr Tamer	McLeod	Adze Hoe	Super Pulaski	Other (specify) Shovel
More line than	11	8	9	2	6	3
Same amount of line as	4	6	6	8	3	0
Less line than	12	3	4	1	7	3
MOPUP *For mopup activities the Reinhartski is:*						
A more effective tool than	1	6	11	3	1	0
Equally effective as	2	9	4	8	1	3
Less effective than	18	0	3	1	13	3
The Reinhartski is:						
More effective than	3	11	10	6	3	0
Equally effective as	1	6	7	4	4	1
Less effective than	19	1	3	2	8	5
More versatile than	4	7	12	5	3	0
Equally versatile as	5	7	1	6	3	2
Less versatile than	15	1	5	1	8	5
OVERALL PERFORMANCE *The Reinhartski produces:*						
Less hand and arm fatigue than	11	10	11	7	9	2
Same amount of hand and arm fatigue as	7	6	7	5	3	1
More hand and arm fatigue than	3	0	1	0	0	1
Less lower back fatigue than	15	7	5	9	10	3
Same amount of lower back fatigue as	4	8	7	2	2	0
More lower back fatigue than	1	0	5	0	1	1
Overall, the Reinhartski is:						
Less fatiguing than	11	9	8	9	12	4
Equally as fatiguing as	12	8	9	3	5	1
More fatiguing than	2	0	1	0	1	2
SAFETY *From an overall safety standpoint the Reinhartski is:*						
Easier to control and safer to use than	11	9	6	6	9	0
Comparable to control and equally safe to use as	7	7	8	4	5	5
Harder to control and less safe to use than	7	1	3	1	1	2
MAINTENANCE *The Reinhartski requires*						
Less sharpening than	6	2	6	4	6	1
Same amount of sharpening as	1	10	7	3	1	3
More sharpening than	18	3	5	3	9	4
Less maintenance than	5	1	1	2	4	0
Same amount of maintenance as	3	9	7	4	3	4
More maintenance than	10	1	4	3	5	3

TOOL PREFERENCE

If you had your choice of tools, what would be your order of preference for the various jobs? (List in order of preference, with 1 being most preferred tool.)

	Reinhartski	Pulaski	Fyr Tamer	McLeod	Adze Hoe	Super Pulaski	Other (specify) (Shovel)
Line Construction—Large project fire or prescribe fire control lines	4	1	6	5	7	3	2
Line Construction—Small fires or spot fires	4	1	6	5	7	3	2
Mopup	3	2	7	5	6	4	1

DESIGN FEATURES

(Check appropriate boxes)

Features	Reinhartski	Fyr Tamer
Handle		
Okay, no improvement needed	19	6
Too short	5	10
Too long	1	0
Need to improve shape (explain)[1]	1	4
Handle-to-Blade Attachment		
Okay, no change needed	18	9
Blade should be angled in more toward handle	2	2
Blade is angled too much toward handle	1	2
Not durable enough	5	0
Blade		
Okay, no improvement needed	7	5
Too light	8	1
Too heavy	0	4
Too wide	0	2
Too narrow	1	0
Not durable enough	9	3
Cutting edge needs to be sharpened differently (explain)[2]	2	1
Other (explain)[3]		

1

2

3

United States Department of Agriculture Forest Service

Clearwater National Forest
Powell Ranger District
Lolo, Montana 59847

APPENDIX B

Reply to 7120 - Equipment Development and Test

Date November 30, 1982

Subject New Fire Tool Evaluation

F. S. R-1 RECEIVED DEC 2 1982 MEDC

To Art Jukkala
Missoula Equipment Development Center

Sorry it took so long to get back to you. We've been busy with some year end maintenance projects. Buck and I talked with each other at the end of the fire season and he wrote a letter with his comments in it. His comments are included with this letter.

We didn't get to use the tools as much as we might, but I think we were able to give them a fair evaluation. Buck's crew ended up with most of the different shaped handles so we didn't evaluate them thoroughly.

Super Pulaski. This was the least preferred tool. It seems unbalanced with a heavy head and people could not develop feel or rhythm for it. With experience, some people might prefer this tool. It is a good trenching tool.

Reverse Edge Pulaski. Comments on this tool differred according to the amount of experience a person had with conventional pulaskis. People with a lot of experience in line digging, myself included, and who have used pulaskis a lot found very little difference between the two. New people liked the reverse edge tool better. They felt that it didn't penetrate as deep as the regular pulaski and you could dig the same amount of line with less swings. They also felt that this tool cut some fuels, such as beargrass and buried roots, better. I attribute the difference in opinion to experience and bias. With practice, you can learn to use the pulaski to dig with shallow easy swings. Also, people who have used pulaskis a long time undoubtably are biased for them. One general comment was that the reverse tool bounced easier and further then the regular tool when it hit something wrong. We had some trouble with sharpening the edge right because of lack of experience.

GI Trenching Shovel. People generally liked this tool. Taller people liked the taller handle and the adjustable feature. They preferred wood over fiberglass because of less shock and more durability. People experimented some with different blade angles, but everyone seemed to prefer the 90 degree angle that we always use. However, if this feature is kept, the head clamp must be improved as it kept coming loose while digging. For myself, the ability to change from a scraping tool to a shovel is a nice feature. Overall, the tool was well liked, it is compact, light, and easy to use and it is good for scraping or rescraping mineral soil. It is not much used for chopping.

Reinhartski and Fyr Tamer. Most of the remarks on the trenching shovel apply to these two tools. The Reinhartski handle and head were preferred for scraping just mineral soil but were incapable of chopping and cutting brush roots, etc. The Fyr Tamer with its heavy head was preferred for general line digging. People felt these tools scraped more soil per swing than pulaskis, etc. and are much easier to learn to use than the conventional shovels.

McLeod. This tool was best used in heavy duff and rotten, punky log situations where a rake was needed for cleaning out the line. It is a fairly good scraping tool, but the Reinhartski type tools are much better.

Shovel. They are hard to dig line with and they take a real technique. They can't be replaced for digging and throwing dirt.

I will bring back the tools we have to Missoula Equipment Development Center. Buck has the rest of the tools with him.

Well, I hope this evaluation is a help to you. Hope you have a good winter and see you next year.

Marshall D. Brown

MARSHALL D. BROWN
Forestry Technician

Enclosure

Fire Handtool Field Evaluation

Background

The Missoula Equipment Development Center (MEDC) has been assigned a project to determine if it is feasible to design a fire handtool that is superior to others for digging fireline. Superior is defined as a tool that produces more fireline for an equal amount of work effort or has comparable production capabilities for less work effort.

Instrumented field tests by MEDC plus field evaluations last summer of Reinhart and Fyr Tamer tools indicated that hoe-style tools with wide scalping blades have considerable promise for improved production and/or reduced work effort.

One shortcoming of this type of tool is that they do not have the dual chopping and digging versatility of the Pulaski. Discussions with many Interagency Hotshot Crew superintendents lead us to believe that most fireline clearing is being done with chain saws and that a chopping capability in all digging tools is not needed.

The modified Reinhart that you are evaluating has the versatility of serving as a shovel as well as a hoe-type digging tool. The primary design considerations favor the hoe configuration. The shovel configuration was given secondary importance and it will not replace a shovel where heavy shovel work is required.

Your objective evaluation of the modified Reinhart tool will be greatly appreciated. Please return completed questionnaires by November 1, 1983, to:

Art Jukkala
A&FM Staff Assistant
Missoula Equipment Development Center
Bldg. 1, Fort Missoula
Missoula, MT 59801
FTS 585-3164
Comm. (406) 329-3164

Individual Evaluator Questionnaire

1983

Fire Handtool Evaluation

Field Unit (Forest, District, etc.)	
Crew Name	
Type Crew: ☐ *Hotshot* ☐ *Helitack* ☐ *Other*	
Your Name	Date

EVALUATOR INFORMATION

Weight ________ Height ________ Age _____ Male _____ Female _____ Aerobic Fitness Score(Step Test or 1½ mile run: ________

Muscular Fitness Data: (if available)

Chinups(no.) ________ Situps(no. in 60 sec.) ________ Pushups(no. in 60 sec.) ________

TYPE OF WORK PERFORMED

	Estimated Hours Used[1] Modified Reinhart
Line Construction—Wildfire	
Line Construction—Prescribed Fire Control Lines	
Line Construction—Fuelbreak or Other Presuppression	
Mopup	
Controlled Tests	
Other(explain)	

SAFETY

	Describe nature of event as appropriate.
Accident	
Injury	
Difficulty Controlling Tool	
Other Safety Concern	

[1] Round off to nearest one-half hour.

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PERFORMANCE COMPARISONS

For each category compare the modified Reinhart tool to other tools you have used.

	Pulaski	Reinhart or Fyr Tamer	McLeod	Adze Hoe	Super Pulaski	Shovel
FIRE CONSTRUCTION						
For an equal period of use the modified Reinhart tool produces:						
More line than	1	1		2		1
Same amount of line as		1	4	2	1	1
Less line than	8	1	5	3	5	7
MOPUP						
For mopup activities the modified Reinhart tool is:						
A more effective tool than	3	3	8	5	3	3
Equally effective as	3		1	1	2	3
Less effective as	3				1	3
OVERALL PERFORMANCE (Hoe configuration)						
The modified Reinhart tool is:						
More effective than	1	3	4	4	1	1
Equally effective as	2		2	1	2	2
Less effective than	5		3	2	3	5
More versatile than	3	2	4	2	2	3
Equally versatile as			1	1	1	1
Less versatile than	5		3	2	2	4
The modified Reinhart tool is:						
Less hand and arm fatigue than	5	2	3	3	4	N/A
Same amount of hand and arm fatigue as	2	1	3	2		N/A
More hand and arm fatigue than	1		3	1	1	N/A
Less lower back fatigue than	6	1	1	3	5	N/A
Same amount of lower back fatigue as	1	2	5	3	1	N/A
More lower back fatigue than	1		2			N/A
SAFETY (Hoe configuration)						
From and overall safety standpoint the modified Reinhart tool is:						
Easier to control and safer to use than	3	1	3	3	2	N/A
Comparable to control and equally safe to use as	4	1	4	2	3	N/A
Harder to control and less safe to use than	2		2	2	1	N/A
MAINTENANCE						
The modified Reinhart requires:						
Less sharpening than	5	1	1	2	3	2
Same amount of sharpening as	1	2	4	1	1	2
More sharpening than	3		4	4	2	3
Less maintenance than	4		1	1	2	1
Same amount of maintenence as	2	2	4	2	2	3
More maintenance than	1		2	2	1	2

TOOL PREFERENCE

If you had your choice of tools, what would be your order of preference for the various jobs? (List in order of preference with 1 being most preferred tool.):

	Modified Reinhart Tool	Pulaski	Reinhart or Fyr Tamer	McLeod	Adze Hoe	Super Pulaski	Shovel
Line Construction—Large project fire or prescribe fire control lines	6	2	7	4	5	3	1
Line Construction—Small fires or spot fires	3	2	7	4	6	5	1
Mopup	3	2	5	7	6	4	1

DESIGN FEATURES

(Check appropriate boxes)

Features	Hoe Configuration	Shovel Configuration
Handle		
Okay, no improvement needed	9	9
Too short	1	1
Too long		1
Need to improve shape (explain)	4	4
Handle-to-Blade Attachment		
Okay, no change needed	3	5
Blade should be angled in more toward handle	1	1
Blade is angled too much toward handle		
Not durable enough	1	
Knuckle nut loosens readily	9	7
Blade		
Okay, no improvement needed	3	4
Too light	4	2
Too small	3	6
Too short		1
Too narrow	1	1
Not durable enough	4	1
Cutting edge needs to be sharpened differently (explain)	4	2
Other (explain)	3	3

Comments:

OTHER

Estimate percent of time tool was used in various configurations.

Hoe configuration: [ ] 0–10% [ ] 10–25% [3] 25–50% [12] 50–100%

Shovel configuration: [3] 0–10% [4] 10–25% [5] 25–50% [2] 50–100%

Is the convertible feature? [ ] Low value [1] Moderate value [14] High value

Do you feel this tool has a place in wildland fire suppression work?

[1] No place [3] Minor place [9] Major place

Describe the tasks, conditions, etc., under which this type of tool will yield the greatest benefits.

____

____

____

____

____

Describe any task, field condition, operator, organization, or other limitations of this type of tool.

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____

____

____

____

Survey Total
Master

8681 2903
June 1985

1985 – EVALUATOR QUESTIONNAIRE

Combination Tool Field Evaluation

Field Unit (Forest, District, etc.)	
Crew Name	
Type Crew: ☐ Hotshot ☐ Smokejumper ☐ Other	
Your Name	Date

BACKGROUND

The Missoula Equipment Development Center (MEDC) has completed a project to design a fire handtool that is superior to others for digging fireline. Superior is defined as a tool that produces more fireline for an equal amount of physical effort or has comparable production capabilities for less physical effort. The result of this project was the development of the Combination or "Combi" tool.

The Combination tool can be used as a: HOE – PICK – HOE/PICK COMBINATION – SHOVEL. It was principally intended for use in the hoe configuration for digging fireline. For this use we estimate that it is about 20 percent more efficient than a Pulaski. The use of five Combination tools on a 20-person crew would be the equivalent to adding the production of one more person to the crew. The "Combi" tool is very versatile. It is very effective for mopup, and hotspotting. It can chop roots 1–1½ inches in diameter, small brush, and seedlings 1–1½ inches in diameter. It can be used to limb small tree branches more safely than a Pulaski. It does, however, lack the Pulaski's capability for chopping larger diameter stems.

A video tape describing some of the key features and applications of this tool is available (call the telephone number below to request a loaner copy).

Your objective comments on this new tool will be greatly appreciated. Please return completed questionnaire by November 1, 1985, to:

Art Jukkala, A&FM Staff Assistant
Missoula Equipment Development Center
Building 1, Fort Missoula
Missoula, Montana 59801

FTS 585-3990
Comm. (406) 329-3990

Work type performed with Combination tool–

Line Construction–Wildfire 2382 (estimated hours used). Line Construction–Prescribed Fire Control Lines 618 (estimated hours used).

Line Construction–Fuelbreak or Other Presuppression 83 (estimated hours used). Mopup 2160 (estimated hours used).

Hotspotting 246 (estimated hours used). Other (explain) ____ (estimated hours used). 8

Estimate percent of time tool was used in various configurations–

Hoe Configuration	☐ 0–10%	6 ☐ 10–25%	4 ☐ 25–50%	43 ☐ 50–100%
Pick Configuration	26 ☐ 0–10%	17 ☐ 10–25%	3 ☐ 25–50%	3 ☐ 50–100%
Shovel Configuration	29 ☐ 0–10%	7 ☐ 10–25%	8 ☐ 25–50%	3 ☐ 50–100%

The convertible feature has: 10 ☐ Low Value 20 ☐ Moderate Value 24 ☐ High Value

What place do you feel this tool has in wildland fire suppression work? 3 ☐ No Place 16 ☐ Minor Place 37 ☐ Major Place

Tool preference. If you had your choice of tools, what would be your first, second and third choice?

	Combination 1	Combination 2	Combination 3	Pulaski 1	Pulaski 2	Pulaski 3	McLeod 1	McLeod 2	McLeod 3	Adze Hoe 1	Adze Hoe 2	Adze Hoe 3	Super Pulaski 1	Super Pulaski 2	Super Pulaski 3	Other (specify) Shovel 1	Other (specify) Shovel 2	Other (specify) Shovel 3
Line Construction (Large project fire or prescribe fire control lines)	12	22	14	31	12	4	2	7	9	3	1	8	2	8	5	6	3	11
Line Construction (Small fires or spot fires)	15	18	11	25	17	4	1	7	10	0	3	6	1	4	10	8	5	11
Mopup	19	16	16	13	26	6	1	0	6	1	0	4	1	4	8	15	6	9

Design features (check appropriate boxes):

HANDLE ☐ Okay, no improvement needed ☐ Too short ☐ Too long ☐ Need to improve shape (explain)
Comments– 23 1 2 9

KNUCKLE JOINT & LOCKING NUT 19 ☐ Okay, no change needed 1 ☐ Blade should be angled in more toward handle
8 ☐ Blade is angled too much toward handle 20 ☐ Unsatisfactory durability
Comments–
Loosens 15
Clogs or jams 17

BLADE 25 ☐ Okay, no improvement needed 9 ☐ Too Light 0 ☐ Too heavy 0 ☐ Too wide 5 ☐ Too narrow
3 ☐ Unsatisfactory durability 9 ☐ Cutting edge should be sharpened differently (explain)
☐ Other (explain) Sharpen serration on Both sides 8
Comments–

PICK 35 ☐ Okay, no improvement needed ☐ Too long ☐ Too short 4 ☐ Unsatisfactory durability
Comments–
Stronger 3

Describe the tasks, conditions, etc., under which this type of tool will yield the greatest benefits:

Mop-UP 13
Hot Line 19
CupTrench 4

Describe any task, field condition, operator, organization, or other limitations of this type of tool:

Rocks 12
Shovel 3
Throwing Dirt 3

Performance Comparisons

For each category compare the Combination tool to other tools you have used

Complete matrix only for tools you normally use

FIRE CONSTRUCTION *For an equal period of use the Combination tool produces:*	Pulaski	McLeod	Adze Hoe	Super Pulaski	Shovel
More line than	22	21	6	4	35
Same amount of line as	20	18	9	5	13
Less line than	29	21	14	18	20
MOPUP *For mopup activities the Combination tool is:*					
A more effective tool than	20	39	19	9	18
Equally effective as	21	12	6	5	28
Less effective as	25	3	1	7	19
OVERALL PERFORMANCE (Hoe configuration) *The Combination tool is:*					
More effective than	13	27	11	4	23
Equally effective as	23	17	16	7	25
Less effective than	29	11	7	15	15
More versatile than	22	41	13	8	34
Equally versatile as	16	5	5	9	12
Less versatile than	13	1	0	5	7
The Combination tool produces:					
Less hand and arm fatigue than	28	15	10	20	N/A
Same amount of hand and arm fatigue as	29	36	14	7	N/A
More hand and arm fatigue than	9	8	2	4	N/A
Less lower back fatigue than	49	9	15	18	N/A
Same amount of lower back fatigue as	10	31	5	1	N/A
More lower back fatigue than	2	6	1	1	N/A
SAFETY (Hoe configuration) *From an overall safety standpoint the Combination tool is:*					
Easier to control and safer to use than	28	17	6	16	N/A
Comparable to control and equally safe to use as	31	33	17	9	N/A
Harder to control and less safe to use than	9	6	4	3	N/A
MAINTENANCE *The Combination tool requires:*					
Less sharpening than	33	7	8	15	15
Same amount of sharpening as	12	29	10	4	20
More sharpening than	15	14	6	4	13
Less maintenance than	9	2	2	7	4
Same amount of maintenance as	11	14	8	7	13
More maintenance than	29	22	11	7	24

We have had the opportunity to use the "second issue" of the Rhinehartskis while on detail to the Powell R.D. The concensus of opinion regarding the effectiveness of these tools is positive. Most of the people that tried them felt that there was a definite place for them in the tool lineup. Most felt that they were superior to the McLeod and a better scraping tool than the shovel.* One of the features that was appreciated was the longer handles. They seem to ease the back strain and made building line downhill easier. The wooden handles were preferred to the fiberglass. The fiberglass handles transferred too much shock and they caused blisters. The increased weight of the head, as opposed to the "first issue", seeemed to help accomplish more work with each stroke. I don't know whether or not the adjustable entrenching head is being planned in the final phases, but the ability to quickly change from a scraping tool to a shovel was extremely convenient and was used frequently by everyone. The curved handles seemed to be appreciated by the users, however, both of the curved handles died prematurely. The "doe's foot" splintered during normal wear and tear. A log rolled over the "S-shaped" handle.

The degrees of set in the head did not appear to make too much difference. Most people did not even realize the angle was different.

The blade configuration that was preferred was that of the Army entrenching tool. That was unamimous among the people that used the tools.

Bitterroot S.O. Crew

*However, the shovel could not be replaced because of its dirt throwing capabilities.

Design Features

Knuckle nut could be made of a sturdier material. Knuckle assembly should be toughened for chopping and pulling action in a hoe configuration.

With the experience that I've had with the Reinhart, I found that the tool, as is, is an excellent tool. The material used to make the blade part might be a little more harder material, a little less tin.

Could have less thick handle.

Handle too thick.

Handle-to-blade attachment doesn't feel solid.

Needs rounder handle.

Cutting and hoeing edge dulls too rapidly.

Blade too light to trench with.

Handle needs to be rounder for side scraping.

(Blade too small) Would like to see large blade for shovel configuration.

(Handle shape) Oblong configuration is ok for hoe but hard to handle as a shovel.

(Blade should be angled in more toward handle) Should make a third adjustment so it can be at about 45-60 degree angle.

Cutting edge not sharp enough.

Point should not have been filed off—would have been a much better digging tool in the original configuration.

Handle: Length of handle is a benefit. You don't have to bend as low to the ground as you do with a Pulaski. It is also good for reaching into areas such as rock, logs, etc. Might be more comfortable if handle was more rounded like McLeod or shovel.

Handle to blade: Best feature of tool. It is convenient to have a tool that can be changed so that a certain job can be done. No looseness noted in the knuckle.

Blade: Because of its size, was easy to use in between rocks, stumps, etc. Probably did a better job in this instance than a McLeod would have. Broke up dirt and small rocks well in hoe configuration. Is difficult to use when cutting roots. Might be better adapted if end of blade was slightly flatter. Has less scraping area than McLeod. When used in a shovel configuration, you must be careful when carrying anything on blade. Is relatively flat and objects can roll off fairly easily. You can reach into areas that you can't with a regular sized shovel. Works well in stump holes, reaching into logs. Is a good mopup tool.

Having used the modified Reinhart tool several times under different circumstances I find it to be best suited for trenching, scraping duff and mopup.

It's very good for trench work. Less fatiguing than a Pulaski.

This is a very useful tool. It is excellent in mopup because of its ability to change from hoe to shovel. Its small size allows it to get in when other tools won't. In building fireline it is good for trenching and scraping. If the blade were squared off instead of rounded it would be much more effective as a scraping tool but then it might not be as good for trenching. The blade is difficult to sharpen in the field. The handle seems to be a little thick (too large of a diameter).

Knuckle nut had to be checked constantly while working. Impedes line construction progress.

The Reinhart is very useful. Excellent for mopup and moving hot rocks and smoldering debris. The adjustment became loose after a few hours of work in rocky terrain. The blade is difficult to sharpen at times due to placement. I was not able to field sharpen this tool, but once in an area that was adaptable, sharpening went well.

Definitely saves wear and tear on lower back.

Knuckle nut needs a locking device.

Blade ok for this type of fire.

As far as the design of the tool goes, the handle and blade were acceptable. The handle to blade attachment had some problems—the most critical being the knuckle nut continually being clogged with sand and grit, and the second problem being the inadequate alloy used on the shank where it attaches to the blade. Other than that we basically liked the tool and look forward to testing the next edition.

Describe The Tasks, Conditions, Etc., Under Which This Type Of Tool Will Yield Greatest Benefits

I think this tool if made stronger to take hot line abuse could be used widely in east side line construction. As a mopup tool it is outstanding because you basically have everything you need in one tool.

The Reinhart can do the various jobs of any other tool. This gives the Reinhart the benefit of being a multiple use tool. One thing I've found that the Reinhart has over any other tool is when scraping charred logs it can be adjusted to different angles or tilted. The serrated edge also does the tool justice in its operation.

Light fuels, rocky soil where you can't get a Pulaski or shovel into some of the tight places—for line construction or mopup.

The tool proved much more effective during mopup with its optional ability. Depending on mopup conditions it could be readily adjusted to complete the tasks more efficiently than most other tools. Yet, it still requires more work because of its small size.

In a shallow duff type soil with no large rocks.

Gardening

Mopup and trenching in soft soils

Trenching and when you have a small group (4-6 people).

We're using it to expose roots for root disease diagnosis.

Worked very well in rocky terrain when used as a scraping tool. Also worked well when used to break up dirt. Works really well in mopup situations. Because of size of blade, ability to change shape, and length of handle, it is a really adaptable tool in mopup.

Most useful in mopup, very useful in trenching and scraping line.

Mopup, trench work, scraping, fireline construction.

Greatest benefit from this tool will be in mopup, but I foresee its use in just about all wild fire situations.

Good in rocky areas or where duff is heavy (+2"). Able to work around tree stumps or brush stands without any hassle in the hoe configuration. Can start excellent scratch line or be used to reach.

This fire was in lava flow area, proved to be excellent for building line, pulling rocks out to find mineral soil. Shovel configuration used to reach into cracks where no other available tool would do the job.

Good on rocky terrain where material is burning beneath rock or for scraping cat faces. Can be used to move hot debris from places no other tool can reach.

We used the modified Reinhart on a 10 day suppression detail and found it to be better than a Fyr-Tamer or the original Reinhart. Under the performance comparisons section in the fire hand tool evaluation, all questions ask that we compare apples to oranges. You've heard the expression, "tool for the fuel" and although the Reinhart might work better than a Pulaski in some instances it is definately not better in all. The same is true when you compare it to the shovel or McLeod. The Reinhart concept has a place in fire suppression, but it seems your expectations fall short of your goals in attempting to replace present suppression tools (or so we gather by the format of your questionnaire).

Describe Any Task, Field Condition, Operator, Organization, Or Other Limitations Of This Type Of Tool

It is not durable enough for dependable hot line construction.

The Reinhart may not be a good hot line tool but for mopup situations it will be hard to beat. At least every engine should carry one, likewise every crew should have 2 or 3 around for use.

Tool is extremely versatile on East side conditions in light fuels, rocky terrain and tight places. In these conditions I would prefer the Reinhart (in line construction) over any other tool except the chainsaw. On West side conditions I don't think it would be very useful. But an extremely good tool in some places (Eastside).

The tool is too light, small, less durable which requires more work to get the job done, particularly in line construction when confronting rocks, big roots and brush. Constant sharpening is needed when using it often under such conditions. Because of its size you must hoe and shovel more which can be significant with shoulder and back muscles. Other tools can easily dig more ground than the Reinhart, but because of its versatility, the Reinhart seems equal and in instances more effective than other tools in mopup operations. The Reinhart needs to have a broader blade, much more sturdier too, and handle narrowed before it will be effective in all aspects of forest fire suppression and other project work in the woods as well as other conventional tools.

Too light for rocks, can't chop large roots.

It's too light to chop, not enough edge for scraping, not big enough blade for shoveling.

Due to the slow fire season we didn't have a great amount of time or conditions to test the tool. We feel the shovel and Pulaski and McLeod have very significant places in the hot shot tool order and to replace these with a specialized tool would be detrimental.

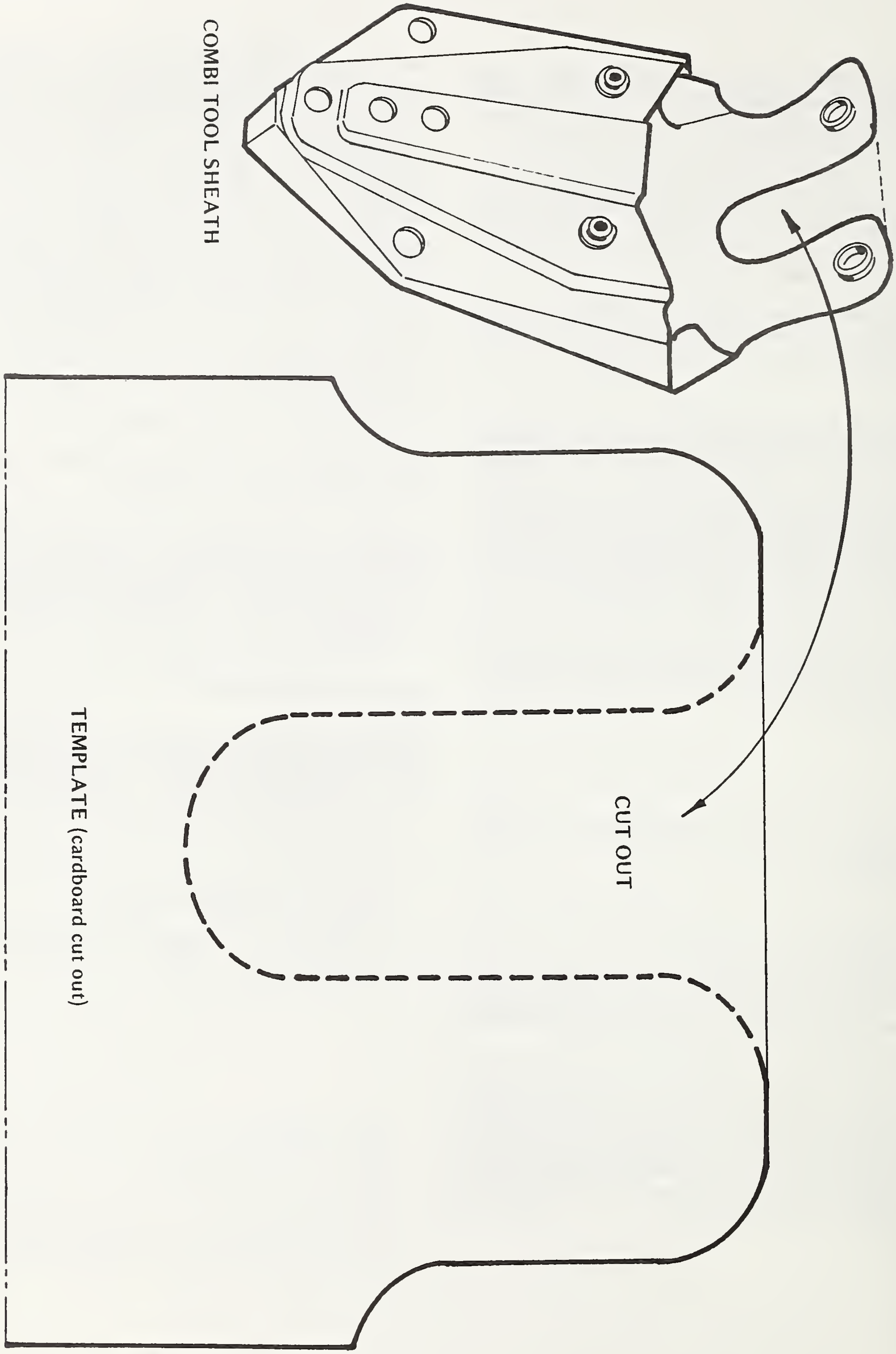
Not a very good cutting tool.

Blade is narrow and pointed and is somewhat difficult to cut with. Scraping area is less than regular sized shovel or McLeod, so operator might have to work just a bit harder to achieve the same results you might with above mentioned tools.

None at this time.

No comment during this fire situation.

Field sharpening is a problem and the knuckle nut becomes loose too often.



COMBINATION "COMBI" TOOL SHEATH MODIFICATION

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